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Climatic Information for Application in Designing and Testing U.S. Army Materiel

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This report provides values and other information for the application of extreme climatic conditions in the RDT&E of Army materiel. Values are given for operational conditions and storage and transit conditions. The two sets of climatic criteria are necessary in order to satisfy requirements that equipment be capable of specified performance levels under all but the most severe natural climatic conditions, and that equipment can survive the most severe expected induced climatic conditions for long periods of time without losing the specified performance capabilities when the more benign natural conditions return.

Climatic criteria are provided for four climatic design types hot, basic, cold, and severe cold Each of these design types is represented by one or more daily weather cycles of temperature, solar radiation, and humidity. Anticipated extreme levels for additional environmental elements (rain, snow, icing phenomena, wind, sand and dust, ozone concentration, freeze-thaw, and atmospheric pressure) are also provided. A map of the areas of occurrence of climatic design types is included to illustrate the distribution of climatic conditions for which criteria are provided. (Keywords)

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SUMMARY

This report provides values for extreme climatic conditions for use in the RDT&E of Army materiel. Values are given for (1) operational conditions and (2) storage and transit conditions. The two sets of climatic criteria are necessary in order to satisfy requirements that equipment (1) be capable of specified performance levels under all but the most severe natural climatic conditions and (2) that equipment can survive the most-severe-expected induced climatic conditions for long periods of time without losing its specified performance capabilities when the more benign natural conditions return.

Climatic criteria are provided for four climatic design types: (1) hot, (2) basic, (3) cold, and (4) severe cold. Each of these design types is represented by one or more daily weather cycles of temperature, solar radiation, and humidity. The hot type has hot-dry and hot-humid cycles; the basic type has hot, cold, constant high humidity, variable high humidity, and cold-wet cycles; the cold and severe cold types have only one cycle each. Data for the climatic criteria are presented in narrative form, and the corresponding 24-hour cycles are given in tables. Anticipated extreme levels for additional environmental elements (rain, snow, icing phenomena, wind, sand and dust, ozone concentration, freeze-thaw, and atmospheric pressure) are also provided.

A map of areas of occurrence of climatic design types is included to illustrate the distribution of climatic conditions for which criteria are provided. For supplementary information on temperature extremes, maps showing the distribution of absolute maximum and absolute minimum temperatures for

the land areas of the world are provided.

The appendix to this report contains a brief analysis of the relationships between the climatic criteria presented herein and the climatic guidance provided in MIL-STD-210B. For overall guidance on policies applying to the use of environmental information in the RDT&E of Army materiel, consult AR 70-38.

PREFACE

This report is intended to fill a gap created when AR 70-38 (RDT&E of Materiel for Extreme Climatic Conditions) was converted to an environmental policy document with a new title (RDTE of Materiel for Realistic Environmental Conditions). Because the policy document contains no values for climatic design criteria, development of a new publication in which to place these data was considered necessary. The continued availability of these climatic design criteria is very important in the development of Army materiel because the standardization and associated guidance provided helps engineers avoid serious problems of overdesigning or underdesigning equipment for its areas of intended use. The information presented in this report will eventually be incorporated with other environmental inputs in a comprehensive AirLand Battlefield Environment (ALBE) report on environmental standards for materiel design.

During FY87 it is expected that the military standard MIL-STD-210C (Climatic Guidelines for Developing Military Equipment) will replace MIL-STD-210B. Most of the climatic design criteria contained in this report will be included in MIL-STD-210C, with the exception of storage and transit conditions. The U. S. Army Engineer Topographic Laboratories will investigate the need for new studies and publications to provide improved criteria and guidance on storage and transit conditions.

This work was accomplished under project 4A76230AT42, task B, work Unit 001, "Improving the Technological Base of Environmental Effects on Materiel."

The work was performed by Dr. Thomas E. Niedringhaus of the Battlefield Environmental Effects Group (BEEG). Cartographic assistance was provided

by Mr. Paul Bourget and Ms Carla P. Ennis of the Geographic Systems Laboratory with help from members of the Terrain Analysis Center, USAETL.

The work was performed under the supervision of Dr. Donald W. Dery, Chief, BEEG; Mr. Regis J. Orsinger, Chief, Land Combat Systems Division; and Mr. Bruce K. Opitz, Director, Geographic Systems Laboratory.

COL Alan L. Laubscher, CE, was Commander and Director and Mr. Walter E. Boge was Technical Director of the U.S. Army Engineer Topographic Laboratories during the period of report preparation.

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1. INTRODUCTION

1.1 Purpose. The purpose of this report is to provide climatic design criteria and related information for use in the Research, Development, Test, and Evaluation (RTD&E) of Army materiel. These data and related guidance were formerly provided in AR 70-38 (1979); however, that document has now been converted to a general policy statement on the entire spectrum of environmental factors that impact the RDT&E of materiel, and no quantitative information on climatic conditions is contained therein. Therefore, in order to make this deleted information available to the user community, the climatic criteria sections of AR 70-38 (1979) are being published as a technical report. This is only an interim solution, however, because in the near future MIL-STD-210C, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment, will be published. This more formal document will embody all the information contained in this technical report (as well as guidance for upper air and sea environments), with the exception of storage and transit conditions. The information provided here will eventually be consolidated with other environmental inputs in a comprehensive report on environmental standards for materiel design.

1.2 Explanation of terms. The following terms have special meanings as defined herein.

1.2.1 Climatic design types. The land areas of the world are divided

into four regional types, based on temperature differences, in order to facilitate the provision of climatic design criteria for materiel intended for worldwide use and for other equipment intended for more restricted use. These regional types are referred to as climatic design types as follows

1. Hot
2. Basic
3. Cold
4. Severe Cold

Areas of the world where these four climatic design types apply are shown in figure 1. The climatic values used to delimit the design types represent extreme conditions that materiel is likely to encounter in the field, with some allowance for risk.

1.2.2 Daily weather cycles. Each climatic design type is characterized by one or more daily weather cycles, which show the interactions and daily patterns of temperature, humidity, and solar radiation (where applicable).

1.2.2.1 Five cycles characterize the basic design type.

a. One cycle represents the hottest days and one the coldest days likely to be found in the basic design areas.

b. Three cycles represent areas where humidity is a major problem. Materiel that can operate satisfactorily under all five of these daily weather cycles should be capable of satisfactory performance throughout the areas shown as basic in figure 1.

1.2.2.2 The hot climatic design type is characterized by two daily weather

cycles, one representing the highest temperatures likely to be found anywhere in the world and the other representing extremely high dewpoints.

1.2.2.3 The cold climatic design type and the severe cold climatic design type are each represented by one daily weather cycle, the severe cold representing the lowest temperatures in which materiel operation is required. For worldwide climatic extremes, the hot-dry daily weather cycle and the severe cold daily weather cycle are applicable. Details of the daily weather cycles that make up the climatic design types are given in the section on climatic criteria.

1.2.3 Operational conditions and storage and transit conditions. In each of the eight daily weather cycles a distinction is made between operational temperature and humidity conditions, and storage and transit temperature and humidity conditions.

1.2.3.1 Operational conditions. These are climatic circumstances in the open to which materiel might be exposed during operations or standby for operations. Ambient temperature and humidity values are those measured under standard conditions of ventilation and radiation shielding in a meteorological shelter at a height of 1.2 to 1.8 meters (4 to 6 feet) above the ground and determined according to the risk policy stated in AR 70-38. Solar radiation that might be measured concurrently with the temperature and humidity is also given for many of the climatic situations. Although the standard conditions measured in meteorological shelters are usually not exactly the same as the operational environment for materiel, it is

necessary to state operational circumstances in standard terms so that:

a. Measurements have the same meaning in all parts of the world.

b. The great range of variations in response of different materiel to a given climatic condition is not a complicating factor in setting design criteria.

For example, the temperature of the materiel itself may vary considerably from the operational air temperature because of the effects of incoming solar radiation, internal sources of heat, the thermal mass, and the heat transfer characteristics of the materials. Most items exposed to the sun will attain higher temperatures than the air temperature. The exact temperature can be obtained through actual or simulated exposure to the appropriate daily cycle or through the development and use of suitable mathematical models. For chamber testing purposes, the heat added by the maximum solar radiation intensity of 1120 W/m^2 (355 $BTU/ft^2/hr$) is often set at 19 to 22°C (35 to 40°F) above the maximum ambient temperature.

1.2.3.2 <u>Storage and transit conditions</u>. These are the temperature and humidity values that materiel might be subjected to in storage and transit situations. Examples of these situations are

a. Inside an unventilated field storage shelter.

b. In a railway boxcar.

Because of great differences in temperature and humidity in varying storage modes, the severity of the exposure depends upon the choice of storage mode as much as upon the storage location. This choice is very important in areas of extreme solar radiation and high humidities. Storage and transit air temperature and humidity may differ from operational temperature and humidity

because of the induced effects of heat gains or losses of air in confined spaces. Where a large thermal mass is involved (e.g., in food storage), the temperature of the stores may be much lower than the storage air temperature stated and may have little daily variation. Temperature for such a thermal mass is derived by using data from previous, similar storage conditions or is determined by actual measurement under current conditions.

1.3 Limitations. The information given in the climatic criteria section is not to be used:

a. In the RDT&E of materiel intended for employment only at a specific place or in a known limited area. This materiel should be designed to withstand climatic conditions at the specific place. In these situations the climatic requirements should be outlined by the combat user in a special study prepared by designated Army environmental specialists (see AR 70-38, para 7 f.(6), or consult with the preparer of this report).

b. In the RDT&E of materiel that has inherent limitations, such as food items or medical supplies that must always be kept in controlled environments. Also excluded are most individual clothing items, which by themselves are not capable of protecting the soldiers from a wide range of climatic conditions. The total range of climatic conditions cited in the section on climatic criteria, however, can and should be used as the guide for developing the required number of clothing ensembles to protect personnel against all conditions they may encounter.

c. To authorize the issue of materiel.

1.4 Application of design values. The general design values given in the

climatic criteria section represent a conservative design approach; that is, there is only a small risk (usually 1 percent of the hours in the most severe month plus an additional small risk in the other months with similar conditions) that the design values will be exceeded in the areas to which they apply. Because there is a finite risk, the design values should be modified for some materiel items. In certain cases failure of an item may be so critical that more severe climatic criteria should be applied to ensure against environment-related failures. In other cases the consequences of failure may be slight, so that the cost of designing to the given values may be unwarranted. Special studies may be required in these cases to determine the most appropriate design values (see AR 70-38, para 7 f. (6)). The type of failure is also an important consideration. Two categories of failure that may cause different design decisions are identified as follows:

1.4.1 Reversible failure. For the duration of climatic extremes the materiel may continue to function, but with its level of performance or safety reduced, or it may cease to function while the extreme conditions prevail. However, when the extreme climatic conditions cease, the materiel will return to normal function.

1.4.2 Irreversible failure. The materiel suffers a failure so damaging during climatic extremes that it will not return to normal function when the extreme climatic conditions cease.

It is Army policy that, at a minimum, all standard general purpose materiel will be designed for safe and effective use in the extreme conditions specified for the basic climatic design Type (defined in Climatic

Criteria section). Materiel intended for use in the extreme climatic design types (hot, cold, and severe cold, as defined under Climatic Criteria) will be provided by designing

a. Special materiel capable of such use.

b. Special materiel solely for such use.

c. Modification kits that adapt new standard materiel or previously type-classified standard materiel to the expected extreme conditions.

The approach chosen will be the one that gives satisfactory results most economically, considering the extent of deployment in each area of potential use, the current technology level, and the time and funding required for development. For example, if equipment is to be developed only for areas where the cold conditions prevail, approach (b) above would apply and the materiel should be designed solely for the cold conditions.

Some materiel (e.g., ammunition) is potentially dangerous to the life or limb of personnel who operate it or handle it under severe environmental conditions. Such materiel will be designed to meet worldwide climatic design requirements for both operational and storage conditions, even though it is not intended for use in all the climatic design types. This policy will prevent situations where materiel developed for limited geographic deployment (e.g., the basic climatic design type) is pressed into emergency use outside its designated area of deployment, where severe climatic conditions could produce catastrophic or extremely dangerous results.

1.5 Climatic testing. Climatic testing is covered in detail in documents such as AR 70-10 and MIL-STD-810D. A limited discussion is included here to indicate the relationship between climatic design criteria and climatic

test values. Although the two sets of criteria are obviously related, there are important differences that should be understood before they are applied.

Materiel under development is always tested in climatic chambers and normally undergoes additional natural (or field) environmental tests.

1.5.1 Chamber climatic test.

1.5.1.1 Simulated climatic tests. The use of simulated tests is encouraged, especially under combined (e.g., temperature and humidity) and sequential conditions. In certain cases, it will not be practical or necessary to duplicate exact conditions of the applicable climatic design values in these tests. The materiel, however, will be tested to meet the guidelines of the requirements document. Developers doing simulated climatic tests should use the daily cycles normally found in nature as their models, rather than chamber testing only at the extreme condition. This daily cycling gives more realistic moisture condensation and temperature response patterns. Test planners and environmental specialists should consult with each other on how the climatic design values apply to testing.

1.5.1.2 Accelerated and aggravated tests. Accelerated tests approximate conditions that may occur in nature, but with a greater frequency or duration than would be expected naturally. Aggravated tests involve subjecting materiel to more extreme conditions than are found in nature. The results of accelerated and aggravated tests are evaluated in terms of what they imply for future service performance. Specifically, they give rapid feedback on problems requiring corrective action, as well as statistical data on the

margin of safety provided by the design. Comparing results of these tests with results of field climatic tests on service performance will give a better interpretation of results. It also increases confidence in the use of such techniques in subsequent, similar situations. In chamber tests, developers are cautioned that subjecting materiel to more extreme conditions than are found in nature may introduce problems that will not occur when testing in the natural environment. (An example is the liquification of TNT, which does not occur at temperatures below 66^{o}C or 150^{o}F.) This is overtesting. On the other hand, the successful conclusion of chamber tests does not guarantee that an item of equipment will operate satisfactorily in the natural environment, because nature involves complex, synergistic effects that cannot in most cases be induced in chambers. Such factors must be considered by the developer when evaluating results obtained in chambers. Test planners and environmental specialists will consult with each other to determine the extreme combinations of conditions that occur in nature.

1.5.2 Natural climatic tests. Although climatic conditions during a field test within a given climatic design type are not likely to be as extreme as the values specified in the section on climatic criteria, there are distinct advantages to conducting tests in a real- world environment where the combined effects of several climatic factors can cause difficulties not revealed by chamber testing. (See additional environmental elements and combined environmental effects in the section on climatic criteria.) On the other hand, when tests are conducted under less than the specified extreme conditions, the adequacy of the natural tests must be reviewed, particularly when test results are marginal. Consideration should then be given to

results obtained under simulated extreme conditions. Data describing climatic conditions prevailing during field tests at the test site will be documented to provide a basis for future evaluation.

2. CLIMATIC CRITERIA

2.1 General. In this section climatic criteria are provided for each climatic design type and the daily cycles of temperature, solar radiation, and humidity. The climatic design types, with their associated daily cycles, are described in general terms in the following paragraphs.

2.1.1 Climatic design types.

2.1.1.1 Hot. The world's highest air temperatures occur in the areas identified with the hot climatic design type in figure 1. These are primarily low latitude deserts, which in addition to very high air temperatures concurrently experience very low relative humidities (except in the hot-humid areas) and intense solar radiation. Two daily cycles make up the hot design type.

a. Hot-dry.

b. Hot-humid.

2.1.1.2 Basic. The humid tropics and the midlatitudes, which the basic design type comprises, are characterized by temperatures more moderate than the extremes of the other design types. Areas where the basic type applies are more widespread than the hot and cold design types combined, as indicated in figure 1. They also include most of the densely populated, highly industrialized sectors of the world. All general purpose Army materiel is

expected to perform satisfactorily under all conditions formally identified as extremes in the basic design type, which is why the type is referred to as "basic." Since microbial deterioration is a function of temperature and humidity and is an inseparable condition of hot- humid tropics and the midlatitudes, it must be considered in the design of all standard general purpose materiel. Five daily cycles are recognized for the basic design type:

a. Constant high humidity.

b. Variable high humidity.

c. Cold-wet

d. Basic hot.

e. Basic cold.

2.1.1.3 Cold. The cold climatic design type areas in figure 1, which are confined to the Northern Hemisphere and isolated high altitude areas in the Southern Hemisphere, have temperatures much lower than the basic cold areas, but not as low as the severe cold areas.

2.1.1.4 Severe cold. The severe cold climatic design type areas in figure 1 have the lowest temperatures on the surface of the earth except Antarctica, which is not considered in this report. These low temperatures are found in the northern continental interiors and the Arctic.

2.1.2 Summary of daily cycles. Table 1 is a summary table of the daily extremes (highest and lowest values in a 24-hour cycle) of temperature, solar radiation, and relative humidity for the eight daily cycles cited in this

Table 1. Summary of Daily Cycles of Temperature, Solar Radiation, and Relative Humidity

Climatic Design Type	Daily Cycle (QSTAG 360 Equivalent)*	Operational Conditions: Ambient Air Temperature °C (°F)	Operational Conditions: Solar Radiation W/m² (Bph)**	Operational Conditions: Ambient Relative Humidity %	Storage and Transit Conditions: Induced Air Temperature °C (°F)	Storage and Transit Conditions: Induced Relative Humidity %
Hot	Hot-Dry (A-1)	32 to 49 (90 to 120)	0 to 1120 (0 to 355)	3 to 8	33 to 71 (91 to 160)	1 to 7
	Hot-Humid (B-3)	31 to 41 (88 to 105)	0 to 1080 (0 to 343)	59 to 88	33 to 71 (91 to 160)	14 to 80
Basic	Constant High Humidity (B1)	Nearly Constant 24 (75)	Negligible	95 to 100	Nearly Constant 27 (80)	95 to 100
	Variable High Humidity (B2)	26 to 35 (78 to 95)	0 to 970 (0 to 307)	74 to 100	30 to 63 (86 to 145)	19 to 75
	Cold-wet	-4 to 2 (25 to 35)	Negligible	95 to 100	-2 to 1 (28 to 34)	95 to 100
	Basic Hot (A2)	30 to 43 (86 to 110)	0 to 1120 (0 to 355)	14 to 44	30 to 63 (86 to 145)	5 to 44
	Basic Cold (C1)	-21 to -32 (-5 to -25)	Negligible	Tending toward Saturation	-25 to -30 (-13 to -28	Tending toward Saturation
Cold	Cold (C2)	-37 to -46 (-35 to -50)	Negligible	Tending toward Saturation	-37 to -46 (-35 to -50	Tending toward Saturation
Severe Cold	Severe Cold (C3)	-51 (-60) (Cold soak)	Negligible	Tending toward Saturation	-51 (-60)	Tending toward Saturation

*Designation in parentheses refer to corresponding climatic categories in Quadripartite Standardization Agreement 360, Climatic Environmental Conditions Affecting the Design of Military Materiel. Two of the QSTAG 360 categories, C0 and C4, are not used by the United States, and there is no QSTAG 360 equivalent for the cold-wet.

**Bph represents British thermal units per square foot per hour.

report. Details of each cycle, and other atmospheric elements (rainfall, icing phenomena, hail, freeze-thaw, wind, blowing sand, blowing dust, ozone, and atmospheric pressure) are given in the following section. In most cases, extremes of these other elements do not occur at the same time as the extremes of temperature or humidity. However, with certain severe cold and cold phenomena, two or more elements may occur at the same time. For example, ice fog normally occurs simultaneously with cold air temperatures (below $-31^{\circ}C$, or $-35^{\circ}F$).

2.2 Details of daily cycles for climatic design types. The following paragraphs, tables, and explanatory information provide climatic design criteria for each of the daily cycles of temperature, solar radiation, and humidity.

2.2.1 Hot climatic design type.

2.2.1.1 Hot-dry cycle.

a. Location. Hot-dry conditions are found seasonally in the deserts of northern Africa, the Middle East, Pakistan and India, southwestern United States, Australia, and northern Mexico (figure 1).

b. Temperature, humidity, solar radiation.

1. Operational conditions. On the extreme hot-dry days, temperature, humidity, and solar radiation may follow a pattern similar to that shown in table 2. Nominal accompanying windspeeds at the time of high temperatures are 4 mps (13 fps). The maximum ground surface temperature of $54^{\circ}C$ ($130^{\circ}F$) is $63^{\circ}C$ ($145^{\circ}F$). At ground elevations above 915 meters (3,000 feet), maximum

Table 2. Hot Climatic Design Type:
Hot-Dry Cycle of Temperature, Solar Radiation, and Humidity
(QSTAG 360 Category A1)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m²	Bph	%	°C	°F	°C	°F	%
0100	35	95	0	0	6	-7	19	35	95	6
0200	34	94	0	0	7	-6	21	34	94	7
0300	34	93	0	0	7	-7	20	34	94	7
0400	33	92	0	0	8	-6	22	33	92	7
0500	33	91	0	0	8	-6	22	33	92	7
0600	32	90	55	18	8	-6	22	33	91	7
0700	33	91	270	85	8	-6	22	36	97	5
0800	35	95	505	160	6	-7	19	40	104	4
0900	38	101	730	231	6	-5	23	44	111	4
1000	41	106	915	291	5	-4	24	51	124	3
1100	43	110	1040	330	4	-6	21	56	133	2
1200	44	112	1120	355	4	-5	23	63	145	2
1300	47	116	1120	355	3	-8	18	69	156	1
1400	48	118	1040	330	3	-9	16	70	158	1
1500	48	119	915	291	3	-8	18	71	160	1
1600	49	120	730	231	3	-7	19	70	158	1
1700	48	119	505	160	3	-8	18	67	153	1
1800	48	118	270	85	3	-9	16	63	145	2
1900	46	114	55	18	3	7	19	55	131	2
2000	42	108	0	0	4	-7	20	48	118	3
2100	41	105	0	0	5	-6	22	41	105	5
2200	39	102	0	0	6	-4	24	39	103	6
2300	38	100	0	0	6	-6	22	37	99	6
2400	37	98	0	0	6	-7	20	35	95	6

air temperatures will be lower by approximately 9.1°C per 1,000 meters (5°F per 1,000 feet) and solar radiation may be higher by approximately 43 W/m^2 per 1,000 meters (4 BTU/ft^2/hr per 1,000 feet) to 4,572 meters (15,000 feet).

2. Storage and transit conditions. The daily cycle for storage and transit in table 2 shows 5 continuous hours with air temperatures above 66°C (150°F) and an extreme air temperature of 71°C (160°F) for not more than 1 hour. Testing for these conditions should be done, if practicable, according to the daily cycle because prolonged exposure to the high temperature extremes may impose an unrealistic heat load on materiel. If use of the daily cycle is not practicable, testing will be done at a temperature representative of the peak temperature that the materiel would attain during a daily cycle.

2.2.1.2 Hot-humid cycle.

a. Location. These severe dewpoint conditions occur only along a very narrow coastal strip (probably less than 5 miles) bordering bodies of water with high surface temperatures, specifically the Persian Gulf and the Red Sea. The hot-humid cycle will be used as a design condition only for systems intended for use or likely to be used in these limited areas. Areas reporting these highest worldwide dewpoints may also experience hot-dry conditions at other times. Tests against hot-humid cycle conditions should be required only for systems that are specified for use in these designated areas.

b. Temperature, humidity, solar radiation.

1. Operational conditions. On days with extremely high dewpoints (high absolute humidity), a cycle such as that in table 3 may occur, along

Table 3. Hot Climatic Design Type; Hot Humid Daily Cycle of Temperature, Solar Radiation, and Humidity. (QSTAG 360 Category B3)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m²	Bph	%	°C	°F	°C	°F	%
0100	31	88	0	0	88	29	84	35	95	67
0200	31	88	0	0	88	29	84	34	94	72
0300	31	88	0	0	88	29	84	34	94	75
0400	31	88	0	0	88	29	84	34	93	77
0500	31	88	0	0	88	29	84	33	92	79
0600	32	90	45	15	85	29	85	33	91	80
0700	34	93	315	100	80	30	86	36	97	70
0800	36	96	560	177	76	31	87	40	104	54
0900	37	98	790	251	73	31	88	44	111	42
1000	38	100	950	302	69	31	88	51	124	31
1100	39	102	1035	328	65	31	88	57	135	24
1200	40	104	1080	343	62	31	88	62	144	17
1300	41	105	1000	317	59	31	88	66	151	16
1400	41	105	885	280	59	31	88	69	156	15
1500	41	105	710	225	59	31	88	71	160	14
1600	41	105	435	147	59	31	88	69	156	16
1700	39	102	210	66	65	31	88	66	151	18
1800	37	99	15	4	69	31	87	63	145	21
1900	36	97	0	0	73	31	87	58	136	29
2000	34	94	0	0	79	30	86	50	122	41
2100	33	91	0	0	85	30	86	41	105	53
2200	32	90	0	0	85	29	85	39	103	58
2300	32	89	0	0	88	29	85	37	99	62
2400	31	88	0	0	88	29	84	35	95	63

with windspeeds between 2.4 and 5.2 mps (8 and 17 fps) and a maximum ground surface temperature of 54°C (130°F).

2. Storage and transit conditions. Induced storage temperatures are presumed to be the same as those for the hot-dry cycle, although relative humidities in the enclosed space are considerably higher.

2.2.2 Basic climatic design type. Five daily cycles represent conditions that may be found in areas where the basic climatic design type prevails. Two of these cycles represent high humidity conditions, two represent the extreme temperatures of the basic set of design values, and the fifth cycle is a combination of temperatures around 0°C (32°F) and plentiful moisture.

2.2.2.1 High humidity daily cycles.

a. Location. Basic high humidity conditions are found most often in tropical areas, although they occur briefly or seasonally in the mid-latitudes. One of the two high humidity cycles (constant high humidity) represents conditions in the heavily forested areas where nearly constant conditions may prevail during rainy and wet seasons. The other daily cycle (variable high humidity) represents conditions found in the open in tropical areas. In the first cycle, exposed materiel is likely to be constantly wet or damp for many days at a time. In the second cycle, exposed items are subject to alternate wetting and drying. Both conditions promote severe deterioration in materiel. The one that is most important, as shown below, depends on the nature of the equipment involved.

Type Materiel	Type of Site with the Highest Deterioration Rates
Elastomers	Open
Polymers	Open
Textiles	Forest
Metals	Coastal swamp (mangrove) and forest

b. Temperature, humidity, solar radiation (constant high humidity cycle).

1. Operational conditions. Relative humidity above 95 percent in association with a nearly constant temperature at 24°C (75°F) persists for periods of several days (table 4).

2. Storage and transit conditions. Relative humidity above 95 percent in association with nearly constant 27°C (80°F) temperature occurs for periods of a day or more.

c. Temperature, humidity, solar radiation (variable high humidity cycle).

1. Operational conditions. The daily cycle outlined in table 5 has a maximum ambient air temperature of 35°C (95°F) for 2 hours. The maximum solar radiation load of 970 W/m^2 (307 $BTU/ft^2/hr$) for not more than 2 hours is accompanied by windspeeds of less than 2 mps (7 fps) and a maximum ground surface temperature of 54°C (130°F).

2. Storage and transit conditions. See storage and transit conditions associated with the hot-humid daily cycle of the hot climatic design type.

d. High humidity chamber testing. Climatic chamber tests can be used to determine whether materiel is likely to resist fungus growth and the mechanical effects of moisture. They cannot be expected to produce the overall effects on materiel that will result from tropical field testing.

Table 4. Basic Climatic Design Type; Constant High Humidity
Daily Cycle of Temperature, Solar Radiation, and Humidity
(QSTAG 360 Category B1)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m²	Bph	%	°C	°F	°C	°F	%
0100	Nearly constant at 24°C (75°F) throughout the 24 hours		Negligible		100	24	75	Nearly constant at 27°C (80°F) throughout the 24 hours		Same as operational conditions
0200					100	24	75			
0300					100	24	75			
0400					100	24	75			
0500					100	24	75			
0600					100	24	75			
0700					98	23	74			
0800					97	23	74			
0900					95	23	74			
1000					95	23	74			
1100					95	23	74			
1200					95	23	74			
1300					95	23	74			
1400					95	23	74			
1500					95	23	74			
1600					95	23	74			
1700					95	23	74			
1800					95	23	74			
1900					97	23	74			
2000					98	23	74			
2100					100	24	75			
2200					100	24	75			
2300					100	24	75			
2400					100	24	75			

Table 5. Basic Climatic Design Type; Variable High Humidity
Daily Cycle of Temperature, Solar Radiation, and Humidity
(QSTAG 360 Category B2)

Local Time	Operational Conditons							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m^2	Bph	%	°C	°F	°C	°F	%
0100	27	80	0	0	100	27	80	33	91	69
0200	26	79	0	0	100	26	79	32	90	70
0300	26	79	0	0	100	26	79	32	90	71
0400	26	79	0	0	100	26	79	31	88	72
0500	26	78	0	0	100	26	78	30	86	74
0600	26	78	45	15	100	26	78	31	85	75
0700	27	81	230	73	94	26	79	34	93	64
0800	29	84	435	138	88	27	80	38	101	54
0900	31	87	630	200	82	27	81	42	107	43
1000	32	89	795	252	79	28	82	45	113	36
1100	33	92	900	286	77	28	83	51	124	29
1200	34	94	970	307	75	29	84	57	134	22
1300	34	94	970	307	74	29	84	61	142	21
1400	35	95	900	286	74	29	85	63	145	20
1500	35	95	795	252	74	30	86	63	145	19
1600	34	93	630	200	76	29	85	62	144	20
1700	33	92	435	138	79	29	84	60	140	21
1800	32	90	230	73	82	29	84	57	134	22
1900	31	88	45	15	81	28	83	50	122	32
2000	29	85	0	0	91	28	83	44	111	43
2100	28	83	0	0	95	28	82	38	101	54
2200	28	82	0	0	96	27	81	35	95	59
2300	27	81	0	0	100	27	81	34	93	63
2400	27	80	0	0	100	27	80	33	91	68

2.2.2.2 Basic hot daily cycle.

a. Location. Basic hot conditions exist in many parts of the world in wide bands surrounding the areas of hot-dry conditions in the United States, Mexico, Africa, Asia, and Australia. They also occur in southern Africa, South America, southern Spain, and southwest Asia.

b. Temperature, humidity, solar radiation.

1. Operational conditions. Design criteria are: 8 continuous hours with an ambient air temperature above 41°C (105°F) with an extreme temperature 43°C (110°F) for not more than 3 hours; a maximum ground surface temperature of 60°C (140°F); solar radiation (horizontal surface) at a rate of 1120 W/m^2 (355 $BTU/ft^2/hr$) for not more than 2 hours (not concurrent with the extreme temperature); a windspeed between 3 and 5 mps (10 and 16 fps) during the period with temperature above 41°C (105°F); and a relative humidity of approximately 14 percent concurrent with the high temperatures (table 6). For elevations of 914-3048 meters (3,000 to 10,000 feet), the ground surface temperature and wind remain the same. Ambient air temperatures, however, decrease 9.1°C per 1,000 meters (5°F per 1,000 feet) and solar radiation increases at a rate of 43 W/m^2 per 1,000 meters (4 $BTU/ft^2/hr$ per 1,000 feet).

2. Storage and transit conditions. Design criteria are: 4 continuous hours with an induced air temperature above 60°C (140°F) with relative humidity less than 8 percent; and air temperature extreme of 63°C (145°F) for not more than 2 hours without benefit of solar radiation and with negligible wind (table 6).

Table 6. Basic Climatic Design Type: Hot Daily Cycle of Temperataure, Humidity, and Solar Radiation. (QSTAG 360 Category A2)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m^2	Bph	%	°C	°F	°C	°F	%
0100	33	91	0	0	36	15	61	33	91	36
0200	32	90	0	0	38	16	60	32	90	38
0300	32	90	0	0	41	17	63	32	90	41
0400	31	88	0	0	44	17	62	31	88	44
0500	30	86	0	0	44	17	62	30	86	44
0600	30	86	55	18	44	17	62	31	88	43
0700	31	88	270	85	41	16	61	34	93	37
0800	34	93	505	160	34	16	61	38	101	30
0900	37	99	730	231	29	17	62	42	107	23
1000	39	102	915	291	24	14	58	45	113	17
1100	41	106	1040	330	21	14	58	51	124	14
1200	42	107	1120	355	18	13	55	57	134	8
1300	43	109	1120	355	16	11	52	61	142	6
1400	43	110	1040	330	15	11	52	63	145	6
1500	43	110	915	291	14	10	50	63	145	5
1600	43	110	730	231	14	10	50	62	144	6
1700	43	109	505	160	14	9	49	60	140	6
1800	42	107	270	85	15	9	49	57	134	6
1900	40	104	55	18	17	10	50	50	122	10
2000	38	100	0	0	20	11	51	44	111	14
2100	36	97	0	0	22	11	51	38	101	19
2200	35	95	0	0	25	12	54	35	95	25
2300	34	93	0	0	28	12	54	34	93	28
2400	33	91	0	0	33	14	58	33	91	33

2.2.2.3 Cold-wet daily cycle.

a. Location. The cold-wet cycle does not have either the coldest or wettest conditions within the basic design type. The extreme feature of this condition is the high frequency of occurrence of freeze-thaw cycles (see additional environmental elements, section 2.3) with accompanying precipitation or high humidities, a combination of elements that places severe stress on many types of equipment. Cold-wet conditions may occur during the transitional seasons in the cold and severe cold climatic design types, but they are much less frequent and accompanied by less precipitation than in the basic type. Cold-wet conditions as herein defined may be found in any place that regularly experiences both freezing and thawing within its daily weather cycle. Such conditions occur most frequently in western and central Europe, the Central and Northeastern United States, southeastern Canada, and northeastern Asia (China, Japan, and Korea). In the Southern Hemisphere cold-wet conditions occur only at moderately high elevations except in South America, where they are found at lower elevations in Argentina and Chile south of 40°S latitude.

b. Temperature, humidity, solar radiation.

1. Operational conditions. Design criteria are: 4 continuous hours with a minimum ambient air temperature of $-4^{\circ}C$ ($25^{\circ}F$) and 3 continuous hours with a maximum temperature of $2^{\circ}C$ ($35^{\circ}F$); a minimum ground surface temperature of $-7^{\circ}C$ ($20^{\circ}F$); a windspeed less than 5 mps (16 fps); negligible heating effects from solar radiation when these temperatures occur; humidity tending towards saturation with dewpoints from $-2^{\circ}C$ to $2^{\circ}C$ ($28^{\circ}F$ to $36^{\circ}F$); a

Table 7. Basic Climatic Design Type; Cold-Wet Daily Cycle
Temperature, Humidity, and Solar Radiation

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	$^{\circ}C$	$^{\circ}F$	W/m^2	Bph	%	$^{\circ}C$	$^{\circ}F$	$^{\circ}C$	$^{\circ}F$	%
0100	-3	26	Negligible during low temperature periods		Tending toward saturation	-3	26	-4	-25	Tending toward saturation
0200	-3	26				-3	26	-4	-24	
0300	-4	25				-4	25	-5	-23	
0400	-4	25				-4	25	-5	-23	
0500	-4	25				-4	25	-5	-23	
0600	-4	25				-4	25	-5	-23	
0700	-3	26				-3	26	-4	24	
0800	-2	28				-2	28	-3	26	
0900	-1	30				-1	30	-1	29	
1000	0	32				0	32	0	32	
1100	1	33				1	33	1	34	
1200	1	34				1	33	2	36	
1300	2	35				1	34	3	37	
1400	2	35				1	34	3	37	
1500	2	35				1	34	3	37	
1600	1	34				1	33	2	36	
1700	1	33				1	33	1	34	
1800	0	32				0	32	1	33	
1900	-1	30				-1	30	0	32	
2000	-2	29				-2	29	-1	30	
2100	-2	28				-2	28	-2	29	
2200	-3	27				-3	27	-2	28	
2300	-3	27				-3	27	-3	-27	
2400	-3	26				-3	26	-3	-26	

trace or more precipitation; and the occurrence of one freeze-thaw cycle in the 24-hour period. Maximum severity to equipment normally is associated with concurrent precipitation because of the effects of alternate expansion and contraction of water during the freeze-thaw process (table 7).

2. Storage and transit conditions. Design criteria are: 4 continuous hours with a minimum induced air temperature of $-5^{\circ}C$ ($23^{\circ}F$) and 3 continuous hours with a maximum induced air temperature of $3^{\circ}C$ ($37^{\circ}F$); no wind or solar radiation; and humidity tending towards saturation (table 7).

2.2.2.4 Basic cold daily cycle.

a. Location. Basic cold conditions are found only in the Northern Hemisphere, generally equatorward of the cold climatic design type areas and on high latitude coasts (e.g., the southern coast of Alaska) where maritime effects prevent occurrence of very low temperatures. Small areas of basic cold weather conditions may be found at high elevations in lower latitudes.

b. Temperature, humidity, solar radiation.

1. Operational conditions. Design conditions are: 5 continuous hours with an ambient air temperature of $-31^{\circ}C$ ($-25^{\circ}F$); a minimum ground surface temperature of $-37^{\circ}C$ ($-35^{\circ}F$); windspeed less than 5 mps (16 fps); negligible solar radiation (horizontal surface); and humidity tending toward saturation (table 8). Saturation is the result of the extremely low temperatures. The absolute humidity and vapor pressure are very low when these temperatures prevail. Although not typical, windspeeds greater than 5 mps (16 fps) may be associated with temperatures of $-31^{\circ}C$ ($-25^{\circ}F$).

2. Storage and transit conditions. Design criteria are: 5 contin-

Table 8. Basic Climatic Design Type; Cold Daily Cycle of Temperature, Humidity, and Solar Radiation (QSTAG 360 Category C1)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m^2	Bph	%	°C	°F	°C	°F	%
0100	-31	-24	Negligible during low temperature periods		Tending toward saturation			-33	-27	Tending toward saturation
0200	-32	-25						-33	-28	
0300	-32	-25						-33	-28	
0400	-32	-25						-33	-28	
0500	-32	-25						-33	-28	
0600	-32	-25						-33	-28	
0700	-30	-22						-33	-27	
0800	-28	-18						-33	-27	
0900	-26	-15						-32	-26	
1000	-24	-12						-31	-24	
1100	-22	-8						-30	-22	
1200	-21	-5						-28	-19	
1300	-21	-5						-27	-17	
1400	-21	-6						-26	-15	
1500	-21	-6						-28	-13	
1600	-22	-8						-29	-15	
1700	-24	-11						-30	-18	
1800	-25	-13						-31	-20	
1900	-26	-15						-32	-22	
2000	-27	-17						-33	-24	
2100	-28	-19						-33	-26	
2200	-29	-21						-33	-27	
2300	-30	-22						-33	-27	
2400	-31	-24						-33	-27	

uous hours with an induced air temperature of $-33^{o}C$ ($-28^{o}F$); no wind or solar radiation; and humidity tending toward saturation (table 8).

2.2.3 Cold and severe cold climatic design types. These types are grouped because they are differentiated only on the basis of the relative severity of their low temperatures, and each design type has only one daily cycle.

2.2.3.1 Cold daily cycle.

a. Location. Cold conditions are found in the Northern Hemisphere in Canada, Alaska, Greenland, northern Scandinavia, northern Asia, and Tibet. Very small areas of the cold type may be found at higher elevations in both the Northern and Southern Hemispheres (e.g., Alps, Himalayas, and the Andes).

b. Temperature, humidity, solar radiation.

1. Operational conditions. Design conditions are: 6 continuous hours with an ambient air temperature of $-46^{o}C$ ($-50^{o}F$); a minimum ground or snow surface temperature of $-46^{o}C$ ($-50^{o}F$); windspeed less than 5 mps (16 fps); negligible solar radiation (horizontal surface); and relative humidity tending towards saturation (table 9).

2. Storage and transit conditions. Same as operational conditions (table 9).

2.2.3.2 Severe cold daily cycle. (Unlike the other seven daily cycles, hourly data for the 24-hour period are not given for the severe cold condition because temperature, solar radiation, and humidity remain nearly

Table 9. Cold Climatic Design Type; Daily Cycle of Temperature Humidity, and Solar Radiation (QSTAG 360 Category C2)

Local Time	Operational Conditions							Storage & Transit Conditions		
	Ambient Air		Solar Radiation		R.H.	Dewpoint		Induced Air Temp		R.H.
	°C	°F	W/m²	Bph	%	°C	°F	°C	°F	%
0100	-46	-50	Negligible		Tending toward saturation			-46	-50	Tending toward saturation
0200	-46	-50						-46	-50	
0300	-46	-50						-46	-50	
0400	-46	-50						-46	-50	
0500	-46	-50						-46	-50	
0600	-46	-50						-46	-50	
0700	-45	-49						-45	-49	
0800	-44	-47						-44	-47	
0900	-43	-45						-43	-45	
1000	-41	-42						-41	-42	
1100	-39	-39						-39	-39	
1200	-37	-35						-37	-35	
1300	-37	-35						-37	-35	
1400	-37	-35						-37	-35	
1500	-37	-35						-37	-35	
1600	-38	-36						-38	-36	
1700	-39	-38						-39	-38	
1800	-39	-39						-39	-39	
1900	-41	-41						-41	-41	
2000	-42	-43						-42	-43	
2100	-43	-45						-43	-45	
2200	-44	-47						-44	-47	
2300	-44	-48						-44	-48	
2400	-45	-49						-45	-49	

constant for one day or longer when such circumstances prevail.)

a. Location. Severe cold conditions are found in the Northern Hemisphere mainly north of the Arctic Circle. In North America they occur in the interior of Alaska, extending into the Yukon in Canada. They also exist in the interior of the northern islands of the Canadian Archipelago and on the Greenland ice sheet. The largest continuous area is in northeast Asia, approximately coincident with Siberia.

b. Temperature, humidity, solar radiation.

1. Operational conditions. The design condition is a minimum temperature of $-51^{\circ}C$ ($-60^{\circ}F$). (For testing purposes, this is a cold soak temperature.) Solar radiation (horizontal surface) is negligible, and relative humidity tends toward saturation (because of low temperature, not high absolute humidity or vapor pressure). Windspeeds are normally less than 5 mps (16 fps). In rare cases where materiel is designated to operate solely in areas where the cold climatic design type applies, the reverse season, or expected maximum, temperature is $35^{\circ}C$ ($95^{\circ}F$).

2. Storage and transit conditions. Same as operational.

2.2.4 High elevation and upper air conditions. For materiel subject to transport through high mountain passes, the temperatures and pressures shown below for elevations as high as 4,572 m (15,000 ft) apply. For materiel subject to shipment by air (elevations as high as 15,240 m or 50,000 ft), the low air pressures and temperatures shown below could result from failure of cabin pressure and temperature control.

Height or Elevation		Pressure	Temperature	
m	ft	millibars (mb)	°C	°F
3,048	10,000	660	-41	-42
4,572	15,000	520	-47	-53
6,096	20,000	410	-56	-68
9,144	30,000	255	-66	-87
12,192	40,000	160	-72	-98
15,240	50,000	100	-76	-105

2.3 Additional environmental elements. Several additional climatic or other environmental elements are known to have effects on some kinds of military materiel. The elements are discussed in the following paragraphs, and where possible, operational extremes are given.

2.3.1 Rain. The world's highest rainfall intensities are in areas that experience the constant high humidity conditions of the basic climates, particularly Southeast Asia. The operational value is an instantaneous (1 minute) rate of 0.80 mm/min (0.03 in/min). Based on data from Southeast Asia, this is the value exceeded only 0.5 percent of the hours in the rainiest month. For certain classes of materiel (e.g., missiles, aircraft) that might be subject to erosion from the more extreme rainfall intensitiess, a design value of 1.80 mm/min (0.07 in/min), derived from the same area, should be considered. This is the intensity that is exceeded only 0.1 percent of the hours in the most extreme month. Much higher rainfall intensities can occur, but they are normally of short duration and usually are restricted to small areas. The highest rainfall intensity ever officially recorded is 31 mm/min (1.23 in/min).

a. A nominal drop-size spectrum for the 0.5 percent extreme is

Drop Diameter Range (mm)

	0.5 - 1.4	1.5 - 2.4	2.5 - 3.4	3.5 - 4.4	4.5 - 5.4	5.5 - 6.4
Number per m^3	2626	342	45	6	1	<1

b. The above rainfall intensities may be accompanied by intermittent winds up to 18 mps (60 fps). Higher windspeeds occur in hurricanes and typhoons (up to 45 mps or 148 fps), along with intense rain that falls almost horizontally, penetrating cracks around doors, hatches, and other vertical openings. Rain affects the performance of electro-optical systems because of its attenuation of electromagnetic radiation in the atmosphere.

2.3.2 Snow. Three aspects of snow are discussed in relation to equipment design. Falling snow also affects the performance of electro-optical systems because of the attenuation and degradation of electromagnetic radiation in the atmosphere.

a. Snowfall rate. No operational extreme is given for rate of snowfall accumulation because for most design applications (excluding battlefield obscuration) the most severe conditions occur when snow is windblown (see 2.3.2.b. below). Worldwide records for extreme snowfall rates are not available. However, the high elevation areas of the western United States probably receive as much snow as any part of the world. The greatest snowfall accumulation in this area during a 24-hour period was 1930 mm (76 in). Crystal sizes of snow particles range from 0.05 to 20 mm diameter, with a median range of 0.1 to 1.0 mm. Larger crystal sizes generally are associated with temperatures near freezing and light winds.

b. Blowing snow. Operational extremes for blowing snow are given in terms of horizontal mass flux of snow particles; that is, the mass of snow moving horizontally across a unit area per unit time. Mass flux decreases significantly with increasing height; highest fluxes are found near the ground up to 2 meters (6.6 feet) in height. Extremes of blowing snow are given for height intervals up to 10 meters (33 feet). Design values should be based on the height of the equipment. The horizontal mass fluxes for operational extremes, with a windspeed of 13 mps (44 fps) at a height above ground or snow surface of 3 meters (10 feet), are

Height		Mass Flux	
(m)	(ft)	(kg/m^2.sec)	(lbs/ft^2/sec)
10.0	33.0	2.2×10^{-3}	$.45 \times 10^{-3}$
7.5	25.0	3.3×10^{-3}	$.68 \times 10^{-3}$
5.0	16.0	4.0×10^{-3}	$.82 \times 10^{-3}$
2.5	8.2	6.9×10^{-3}	1.40×10^{-3}
1.0	3.3	16.0×10^{-3}	3.30×10^{-3}
0.75	2.5	22.0×10^{-3}	4.50×10^{-3}
0.5	1.6	32.0×10^{-3}	6.60×10^{-3}
0.25	0.82	66.0×10^{-3}	14.00×10^{-3}
0.1	0.33	200.0×10^{-3}	41.00×10^{-3}
0.15	0.16	530.0×10^{-3}	109.00×10^{-3}

When blown by strong winds, snow crystals are shattered and abraded into more uniform sized grains with rounded or subangular corners. More particles occur in the size range of 0.02 mm to 0.4 mm, where the size is the effective diameter defined as $\sqrt{\text{length X breadth}}$ in the plane of measurement. Smaller sizes tend to occur with higher winds at lower temperatures. Within the basic cold regions, the typical temperature range during periods of blowing snow is $-10^{o}C$ to $-20^{o}C$ ($14^{o}F$ to $-4^{o}F$). Within the cold and severe cold regions, snowfall is common at temperatures between $-23^{o}C$ to $-29^{o}C$ ($-10^{o}F$ to $-20^{o}F$). Blowing snow may occur at temperatures as low as $-40^{o}C$ ($-40^{o}F$).

c. Snowload. A third important effect of snow is the structural load imposed by accumulated snow upon buildings, shelters, vehicles, or other relatively large military items. Snowload extremes are not applicable to operations; however, designers of the above items may wish to consider the following extremes, which are for snowloads on the ground. Snowloads on military equipment would usually be less than on the nearby ground.

1. Portable equipment usually involves small items, such as tentage, which may be moved daily. This equipment generally will shed snow, but in instances where it does not, distortion will be noticeable and daily cleaning mandatory. The design criterion for this equipment is based on 24-hour snowfalls. The snowload value is 48.9 kg/m^2 (10 lbs/ft^2), which is equivalent to a depth of 508 mm (20 in) of snow with a specific gravity of 0.1.

2. Temporary equipment usually involves large items on which snow can collect: rigid shelters, portable hangars, etc., which can be cleared of snow between storms. This equipment will not sag much from the snow loading but may collapse when its limits are exceeded. The design criterion for this equipment is based on snowfalls associated with storms lasting longer than one day. The snowload value is 97.7 kg/m^2 (20 lbs/ft^2), which is equivalent to a snow depth of 1016 mm (40 in) with a specific gravity of 0.1.

3. Semipermanently installed equipment is usually demountable and not very mobile. Snow is not removed between snowfalls. The design criterion for this equipment is based on seasonal accumulation of snow. The snowload value is 235 kg/m^2 (48 lbs/ft^2), which is equivalent to a snow

depth of 2438 mm (96 in) with specific gravity of 0.1.

2.3.3 Icing phenomena. Icing phenomena include glaze (freezing rain), hoarfrost, rime, and ice fog, which cause problems of ice accretion on aircraft and other materiel and interfere with visibility. Although reliable and systematic data on ice accumulation are scarce, fairly large areas of the United States and Europe can expect to endure seven or more ice storms per year. Ice accumulation from these storms may last from a few hours to several days. In the same areas, probably one storm per year on the average is severe enough to cause some damage. In perhaps one year out of two or three, ice accumulation will probably be 13 mm (one-half in) or more. Therefore, if all-weather operation of materiel is desired within the areas where icing may occur the operational design value should be for 13 mm (one-half in) of glaze with a specific gravity of 0.9. This includes the colder sections within the basic design type and all of the cold and severe cold areas. If equipment failure during the time of icing can be tolerated, the question of withstanding more severe storms without permanent damage becomes important. For withstanding, the values as given in MIL-STD-210B are as follows:

3 in (76 mm) glaze, specific gravity 0.9.

6 in (152 mm) glaze and rime mixed, specific gravity 0.5.

6 in (152 mm) rime near the surface, increasing linearly to 508 mm (20 in) at 122 m (400 feet), specific gravity 0.2.

a. Deposits of hoarfrost, which is one type of ice accretion that occurs when air temperatures are well below $0^{o}C$ ($32^{o}F$), may be several inches thick, and has a specific gravity of less than 0.2.

b. Ice fog consists of suspended ice crystals averaging 5 to 20 micrometers in diameter. In areas where sufficient water vapor is present, ice fog occurs daily at temperatures below -37°C (-35°F). Ice fog may be very dense and can limit horizontal visibility to a few feet. Ice fog is often locally induced by the operation of motor vehicles, power plants, and weapon systems. It is usually high in concentration of contaminants from the burning of hydrocarbon fuels and explosive fuels. It affects the performance of electro-optical systems because of its attenuation and degradation of electromagnetic radiation in the atmosphere.

2.3.4 Hail. Hail, which is mostly associated with thunderstorm activity, occurs too infrequently to warrant specification of an operational extreme. When hail-caused equipment failure would endanger life or limb, designers should consider the possibility of encountering hailstones up to 51 mm (2 in) in diameter. The largest hailstone ever recorded measured 142 mm (5.6 in) in diameter.

2.3.5 Wind. Wind is probably the most complex of all climatic elements affecting materiel. Wind effects are difficult to analyze because wind is a vector quantity subject to rapid temporal and areal changes in speed and direction. In addition to parameters of average speed and direction, a complete description of wind includes the random motions of widely different scales and periods called atmospheric turbulence or eddies. The wind forces on a structure result from differential pressures, positive and negative, caused by an obstruction to the free flow of the wind. Thus, these forces are functions of the velocity and turbulence of the wind and of the orienta-

tion, area, and shape of the elements of the structure.

a. For operations, the following extreme as given in MIL-STD-210B is a steady windspeed of 22 mps (73 fps).

b. The above operational windspeed is for a height of 3 m (10 ft). Multiplication factors for obtaining speeds at the height of equipment are

Height (m)	Height (ft)	Operation Steady Winds	Operation Gusts
1.5	5	0.917	0.946
3	10	1.000	1.000
6	20	1.090	1.057
9	30	1.147	1.092
12	40	1.189	1.117
15	50	1.222	1.137
23	75	1.286	1.175
30	100	1.334	1.202
61	200	1.454	1.271
91	300	1.500	1.313
122	400	1.586	1.343
152	500	1.631	1.368
305	1000	1.778	1.445

2.3.6 Sand and Dust. Sand and dust are usually differentiated on the basis of particle size, although there are no generally accepted specific size limits for the two kinds of particles. For most military applications it is important to distinguish between the smaller particles (dust) and the larger particles (sand) because of their different effects on equipment. Dust can penetrate small openings, cause undue wear to moving parts, and interfere with electrical contacts. Blowing sand, which may be too large to penetrate the smaller openings, can erode and abrade the outside of equipment. Sand and dust in the air affect the performance of electro-optical systems because of their attenuation and degradation of

electromagnetic radiation in the atmosphere. Particles vary in diameter from 0.1 to 1,000 micrometers (3.94×10^{-6} in to 3.94×10^{-2} in), but most airborne particles are less than 74 micrometers (2.91×10^{-3} in).

a. Three operational levels are given; selection of the appropriate one depends on the intended use of the materiel under consideration. Items likely to be used in close proximity to aircraft operating over unpaved surfaces should be designed for particle concentrations of about 2.19×10^{-3} kg/m^3 (1.32×10^{-4} lb/ft^3) in multidirectional strong winds (downwash from helicopter rotors). Such particles range in size up to 500 micrometers (1.97×10^{-2} in) in diameter. Items never used or never exposed in close proximity to operating aircraft, but which may be found near operating surface vehicles, should be designed for particle concentrations of 106×10^{-3} kg/m^3 (6.61×10^{-5} lb/ft^3) with windspeeds up to 18 mps (59 fps) at a height of 3 m (10 ft). Particle sizes will range from less than 74 micrometers (2.91×10^{-3} in) in diameter to 1,000 micrometers (3.94×10^{-2} in), with the bulk of the particles ranging in size from 74 to 350 micrometers (13.8×10^{-3} in).

b. The above two categories are likely to include most military items. However, items that are ensured of being subjected only to natural conditions should be designed for particle concentrations of 0.177×10^{-3} kg/m^3 (1.10×10^{-5} lb/ft^3) with windspeeds of 18 mps (59 fps) at a height of 3 m (10 ft). Under these conditions, most particles are likely to be less than 150 micrometers (5.90×10^{-3} in) in diameter except that some large particles (up to 1,000 micrometers) may be in motion within several feet of the ground. In all categories temperatures are typically above 21°C (70°F) and relative humidities are less than 30 percent. For testing purposes, particle sizes up

to 150 micrometers should be used if the primary concern is the penetration of fine particles. If the abrasion effect of blowing sand is the primary concern, particle sizes up to 1,000 micrometers should be used, but the bulk of the particles should be between 150 and 500 micrometers. Many items, such as rifles, vehicles, and helicopters, may be exposed to particles up to 1,000 micrometers that can penetrate the space between moving parts.

2.3.7 Ozone concentration. For operations, a value of 220 X 10^{-3} kg/m^3 (1.37 X 10^{-8} lb/ft^3) is recommended.

2.3.8 Atmospheric pressure. Atmospheric pressure usually is not considered in the design and testing of military equipment. Ambient pressure, however, may be important for a few types of equipment, for example, items that require oxygen for combustion, and sealed units, which might explode or collapse under abnormally low or high pressure.

a. High pressure. The operational extreme high pressure is 1,080 mb (31.89 in).

b. Low pressure. The operational extreme low pressure is estimated to be 508 mb (15.00 in) at 4,572 m (15,000 ft), the highest elevation at which Army equipment is likely to be used. At sea level the operational extreme is 877 mb (25.90 in).

2.3.9 Freeze-thaw cycles. A freeze-thaw cycle occurs at a specific site on any day that the temperature at that place crosses the freezing mark; thus both freezing and thawing occur within the 24-hour period. Unlike the other climatic elements in this report, which are given in terms of their

magnitudes, freeze-thaw is a discrete variable and can only be expressed in terms of its frequency of occurrence. Although it is theoretically possible for more than one freeze-thaw cycle to occur at any place during a 24-hour period, this is not very common because of the normal control of the daily temperature cycle by the solar cycle.

Freeze-thaw conditions can cause significant problems with many kinds of materiel and should be given consideration in the design of all materiel to be used in the areas where freeze-thaw cycles occur. It is particularly important in areas where there is abundant moisture in the atmosphere so that condensation and precipitation are common. The freezing and thawing of water in exposed components of materiel can create great internal stress and damage.

Operational values are not appropriate for this element. However, equipment should be designed to withstand at least 20 cycles during the most severe month, with concurrent dewpoints of $-2^{o}C$ to $2^{o}C$ ($28^{o}F$ to $36^{o}F$), a trace or more precipitation on the day of the cycle, and humidities tending toward saturation.

2.4 <u>Combined environmental effects</u>. The climatic design types in this report are based primarily on temperature extremes and secondly on humidity extremes. The climatic elements discussed in the preceding section, however, may interact concurrently with temperature and humidity and with each other to produce effects on materiel either different from or more severe than the sum of the effects caused by the separate elements acting independently. These are known as combined or synergistic environmental effects. The fact that these synergistic effects exist is one of the prime arguments for

conducting field tests, because it is extremely difficult or impossible to reproduce the interacting environmental factors concurrently in a test chamber.

3. DISTRIBUTION OF CLIMATIC DESIGN TYPES

3.1 Map of climatic design types. Figure 1 shows land areas where the four climatic design types apply. Discussion of the delimitation of the climatic conditions in the following paragraphs is included to permit proper interpretation and use of the map.

3.2 Delimitation of climatic design types. The primary basis for delimiting the climatic conditions in this regulation is temperature; secondary consideration is given to humidity conditions.

3.2.1 Hot climatic design type. The areas where hot conditions apply include most of the low latitude deserts of the world. During summer in these areas, temperatures above 43°C (110°F) occur frequently, but except for a few specific localities, temperatures will seldom be above 49°C (120°F). In winter, temperatures are not likely to be extremely low; therefore, the low temperatures of the basic climatic design type apply. If materiel is designed only for the hot type, a special recommendation for low temperature design values should be sought. Limited portions of this area are sometimes subject to very high absolute humidities, although the highest temperatures and highest dewpoints do not occur at the same time.

3.2.2 Basic climatic design type. The area this type applies to includes the most densely populated and heavily industrialized parts of the world as well as the humid tropics. The entire range of basic design conditions does not necessarily apply to any one place. Each single design condition (high

temperature, low temperature, high humidity) applies to a widespread area. When taken together, the design values should provide for satisfactory equipment throughout the area involved. Tropical areas are included in the basic climatic design type because the temperature of the humid tropics is moderate (no very high or very low temperatures), and the humidity is also experienced in the midlatitudes. The unique feature of the tropics that makes them important in materiel considerations is the persistence of high humidity over long periods of time. This condition not only promotes corrosion but also is an excellent environment for insect and microbiological damage.

3.2.3 Cold and severe cold design types. The areas designated as cold and severe cold, primarily northern North America, Greenland, northern Asia, and the Tibetan Highland of China, were delimited because of the occurrence of low temperatures. In the area of the cold design type, temperature during the coldest month in a normal year may be colder than the basic cold extreme of $-32^{\circ}C$ ($-25^{\circ}F$), but colder than the cold extreme of $-46^{\circ}C$ ($-50^{\circ}F$) for no more than 1 percent of the time in the most extreme part of the area. In the severe cold areas, temperatures may be expected to be lower than $-46^{\circ}C$ ($-50^{\circ}F$) more than 1 percent of the time in the most severe month, but not colder than $-51^{\circ}C$ ($-60^{\circ}F$) for more than 20 percent of the hours during the most severe month in the coldest part of the design type (i.e., northern Siberia, where absolute minimum temperatures as low as $-68^{\circ}C$ ($-90^{\circ}F$) have been recorded). Because the extreme low temperatures are not controlled by a daily solar cycle, they persist for sufficient time for materiel to reach equilibrium at a temperature near the minimum.

APPENDIX A

RELATIONSHIP BETWEEN CLIMATIC CRITERIA IN THIS REPORT AND THOSE IN MIL-STD-210B

A-1. Background. To provide background for the proper application of the climatic criteria in this report, their relationship to MIL-STD-210B (Climatic Extremes for Military Equipment) is outlined. There are two principal differences between the two approaches.

a. MIL-STD-210B applies only to materiel developed for worldwide use, for ground, sea and air . This report, which applies only to U.S. Army materiel, which is primarily ground equipment, provides both worldwide extremes and sets of criteria for materiel intended for less than worldwide use (more limited geographic deployment).

b. The MIL-STD has withstanding values*, but no storage and transit conditions. This report has storage and transit conditions, but no withstanding values. Storage and transit conditions are induced rather than natural occurrences and are highly dependent on the type of materiel and the method of storage or transportation. Withstanding values reflect natural conditions, but are such rare occurrences that materiel is expected only to withstand them, not operate in them. Both MIL-STD-210B and this report reflect a philosophy that accepts a small risk of failure during periods of extreme weather. They also require a complete return to operation after

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* Withstanding values are determined by the risk that the given value of the climatic element will occur at least once during the expected duration of exposure in the most severe area for the element. In MIL-STD-210B, the accepted risk for determining withstanding values is 10 percent for equipment expected to be exposed for 2, 5, 10, and 25 years.

exposure to extreme conditions has ended. It should be understood that the worldwide operational extremes in the two documents are the same. However, MIL-STD-210B is limited to natural extremes, whereas this report, based on the values developed for AR 70-38 (1979), also includes the induced conditions of storage and transit. Consequently, Army materiel must be able to survive much higher air temperatures than the extremes given as operational values in MIL-STD-210B.

A-2. Risk policy. In the Ground Environment section of MIL-STD-210B, single worldwide values are given for each climatic element to be considered in the design of materiel for operational conditions. For high temperature and several other climatic elements, the design value selected was the value equalled or exceeded not more than 1 percent of the hours in the most extreme month in an average year at the most severe location. For low temperature the level selected was 20 percent of the hours, and for rainfall the values were based on 0.5 percent of the hours. These percentages were approved in 1969 by the Joint Chiefs of Staff, based on guidance from the Tri-Service Committee for the Revision of MIL-STD-210A. These values are often referred to as 1 percent design values, although low temperatures and rainfall use different percentages. When the values are applied collectively, they are often referred to as a 1 percent risk policy. Although this may be a convenient short designation, it can be misleading to those who are not aware of this specific definition of a 1 percent risk policy. In fact, there is no way to quantify, with any degree of accuracy, the probability that materiel will ever encounter a given extreme of an environmental element. However, it can be stated with assurance that

the designated 1 percent risk levels as used in MIL-STD-210B are very conservative. For example, on a year-round basis, the risk of encountering the design level of a selected element approaches one-twelfth of 1 percent (there is some likelihood of occurrence in other than the most extreme month). Also, for many of the climatic elements, the design value applies only to the most severe location in the world. Therefore, the risk of materiel encountering this extreme may be very small, particularly if the value at the most severe location is representative of only a small area or if the location is in a remote part of the world.

The above consideration led to the adoption of the system originally developed for AR 70-38 and now transferred to this report. This system provides alternative design values for items not intended for worldwide (land areas only) use. Consequently, the land area of the world was divided into four types on the basis of temperature characteristics. Except for the hot-dry and severe cold, which are worldwide extremes and determined on the basis of the risk policies described above, the design temperatures selected to delimit these climatic types are somewhat arbitrary. However, the high and low temperatures selected for the basic design type resulted in a geographic area that constitutes not only much of the earth's landmass but also most of its population, agriculture, and industry. In general, the lines delimiting the areas included in a design type have the same basis as MIL-STD-210B; that is, the value selected is the one that is equalled or exceeded 1 percent of the hours in the most severe month on the average. Note, however, that these are delimitation values and that it is only along the demarcation line that this criterion applies exactly. For example, if more than 1 percent of the hours in the coldest month at a given location

are below $-46^{\circ}C$ ($-50^{\circ}F$), the area represented by that location is considered part of the severe cold climatic design type. Yet, at that location there may be only a very small chance of occurrence of $-51^{\circ}C$ ($-60^{\circ}F$), which is the lower design temperature for the severe cold type. On the other hand, there are places in the severe cold design type that have temperatures colder than -51° ($-60^{\circ}C$) for as much as 20 percent of the hours in the coldest month. This kind of internal variation within the various types could be eliminated only by creating a large number of small regions, a procedure that would make this design criteria guidance unduly complex and probably would not be good design policy.

A-3. Additional guidance. General guidance such as embodied in this report cannot possibly address in detail the environmental considerations for all materiel. Thus, users are encouraged to seek additional or more specific guidance from the office that prepared this report: U.S. Army Engineer Topographic Laboratories, ATTN: ETL-GS-AE, Fort Belvoir, VA 22060-5546. For questions of broad policy on the application of environmental information to the RDT&E of Army material, consult AR 70-38 or the proponent agency for that regulation: HQDA (DAEN-RD), WASH, DC 20314.

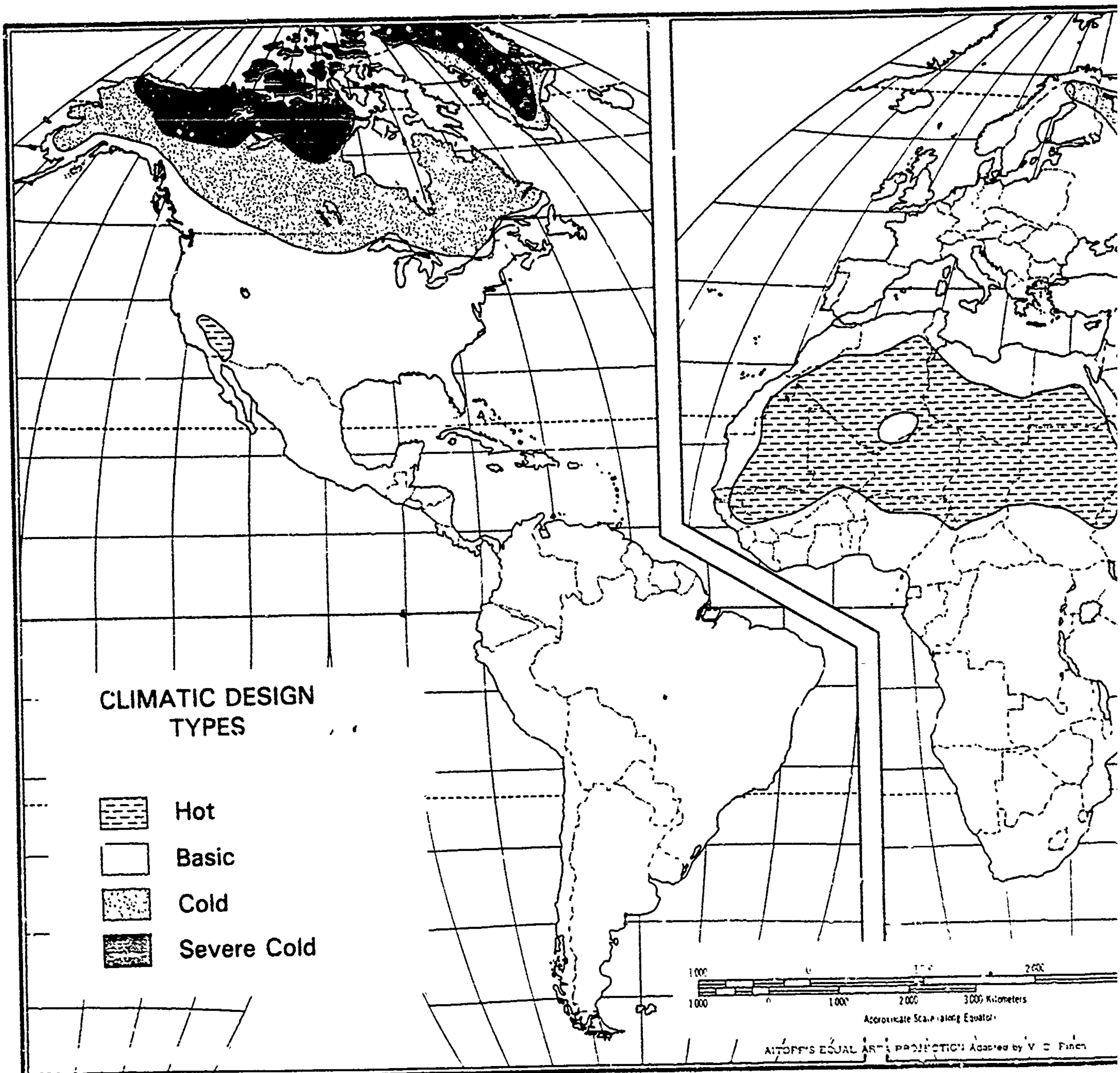
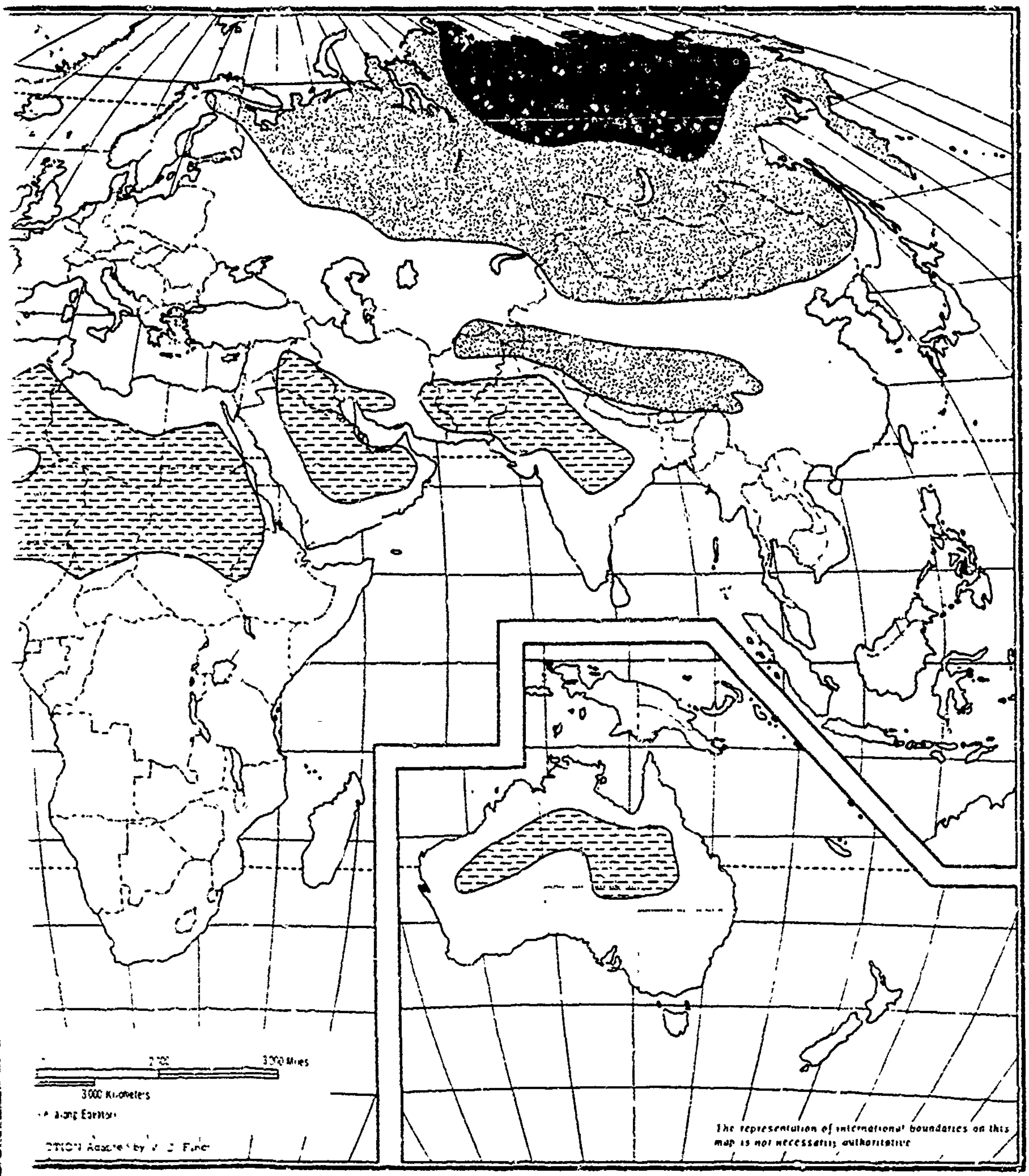


Figure 1. Areas of Occurrence of Climatic Design Types


3000 Miles
3000 Kilometers
The representation of international boundaries on this map is not necessarily authoritative

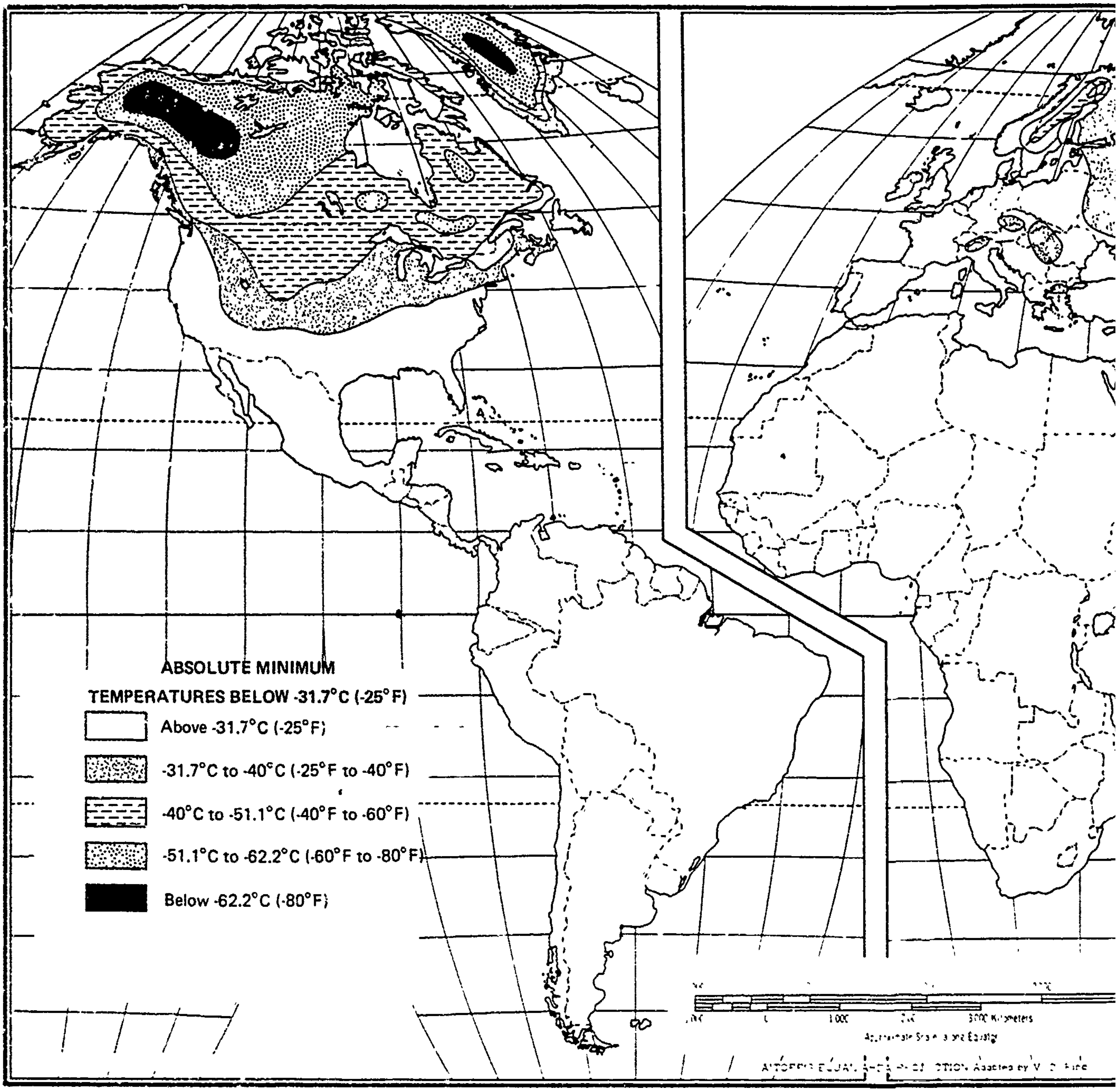
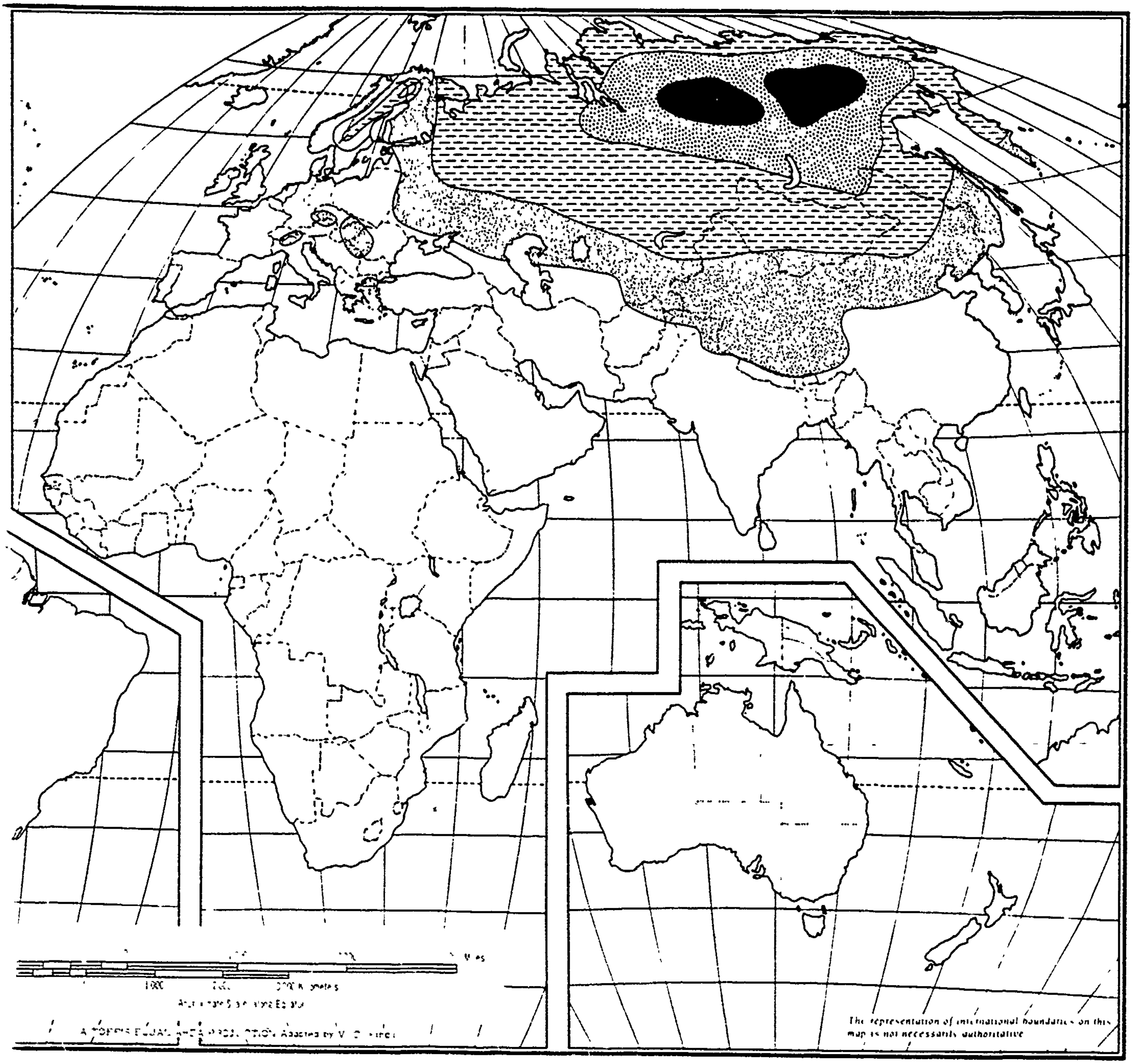


Figure 3. Distribution of Absolute Minimum Tem



3. Distribution of Absolute Minimum Temperatures

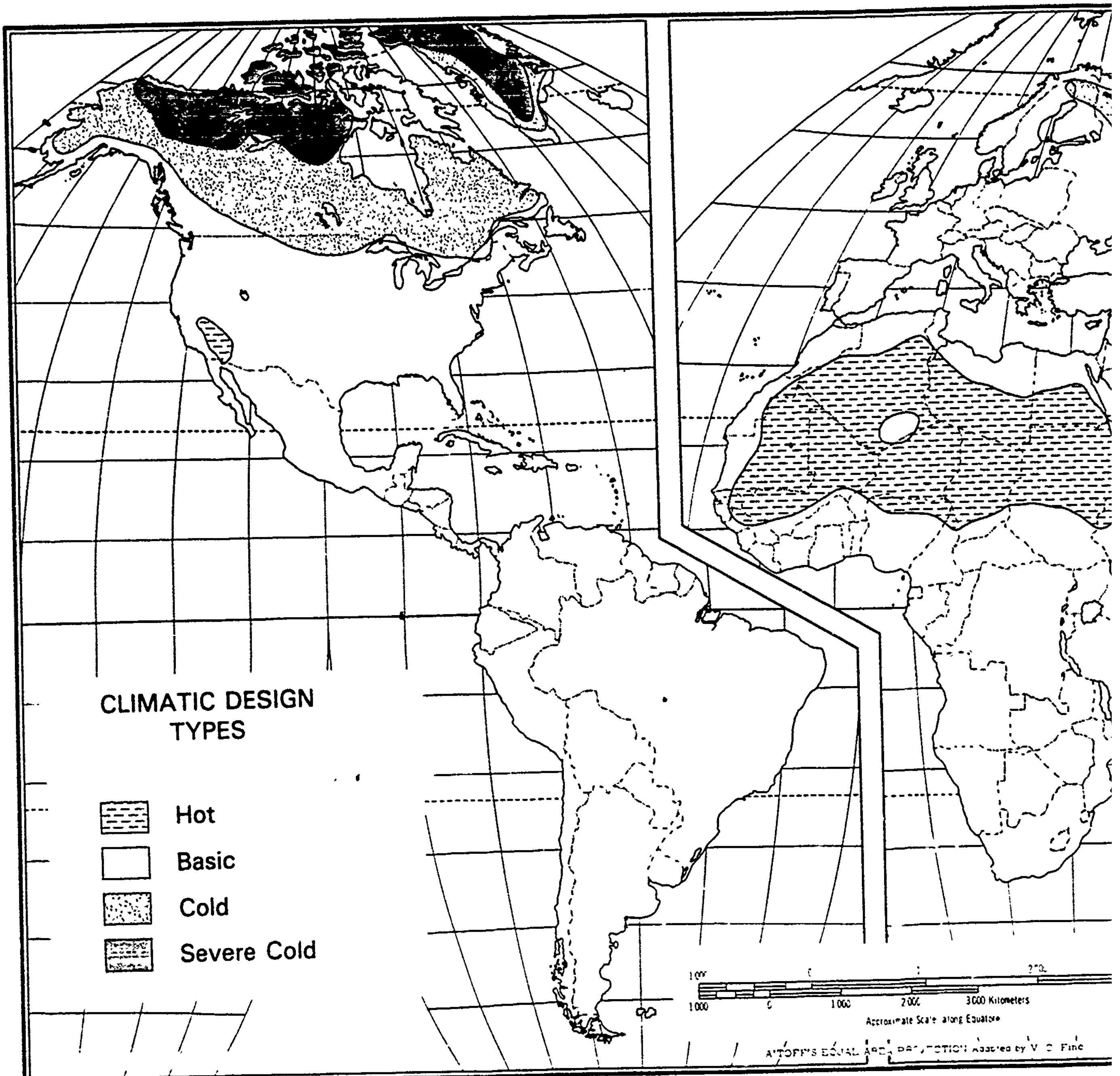
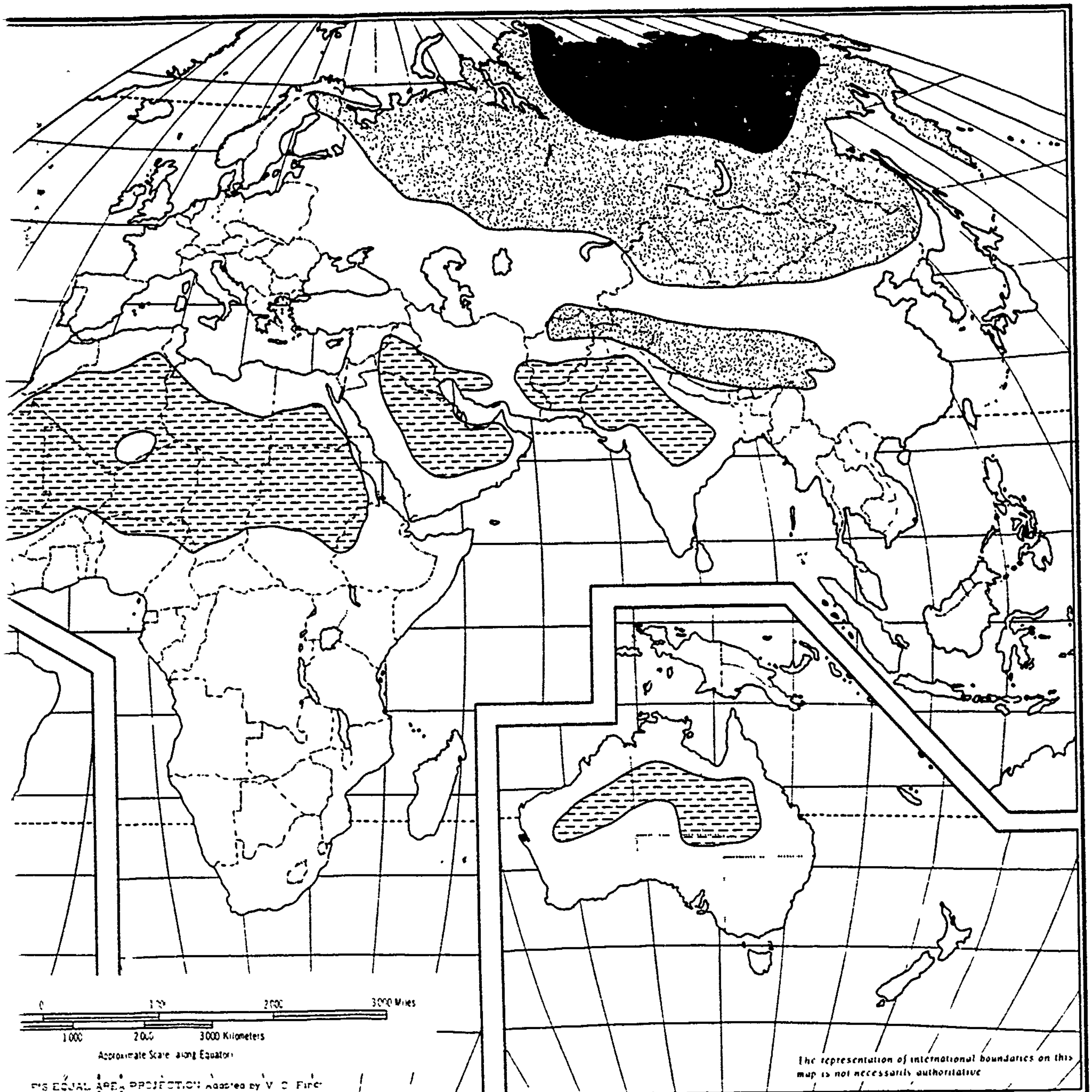


Figure 1. Areas of Occurrence of Climatic Design Types



0
2000
3000 Miles
1000
3000 Kilometers
Approximate Scale along Equator
The representation of international boundaries on this map is not necessarily authoritative